REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

AD-A231 945

RT DATE	3. REPORT TYPE AND DATES COVERED
26 Dec 90	Final Tech 01May90 to 30Apr91

Workshop on High Temperature Metal-Ceramic Composites, Aurora NY Sept 10-11, 1990

5. FUNDING NUMBERS

(G) AFOSR-90-0230

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8. PERFORMING ORGANIZATION REPORT NUMBER

MCWKSHP90

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER

AFOSR-TR- 91 0025

2306/A1

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release;
distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The workshop on high temperature metal-ceramic interfaces was held in Aurora NY for two full days on Sep 10 & 11, 1990. Thirty five non-Cornell scientists, two of them from abroad, and ten Cornell scientists attended the workshop. They represented industry, universities and national laboratories. Five sessions were held with about equal time devoted to presentations and discussion. The subjects were measurement of the local mechanical properties of interfaces, constrained deformation, reactions at metal ceramic interfaces, new materials, and the atomic and electronic structure of metal-ceramic interfaces. The principal findings of the workshop were as follows: (i) scientific and fundamental guidelines are needed for the design of metal-ceramic composites, (ii) much greater emphasis needs to be placed on the study of high temperature properties of such composites, (iii) physical metallurgy of interfaces, that is, the reactions at interfaces should be studied as a function of oxygen activity and the effect of these reactions on mechanical properties understood, (iv) local deformation on the scale of dislocation spacing near the metal-ceramic interfaces needs to be examined, and (v) the theoretical understanding of the atomic and electronic structure and bonding of such interfaces is ready for important advances.

14. SUBJECT TERMS

Interfaces, MMC, Oxidation, Composites, Fracture

15. NUMBER OF PAGES

7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

FINAL TECHNICAL REPORT

Workshop on Tailored Interfaces for High Temperature
Metal Ceramic Composites

September 10 - 11, 1990
Aurora Inn
Aurora NY

to

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AFOSR/NE
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by

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December 26, 1990

Introduction

Current research on interfaces in metal-ceramic composites is rapidly evolving into a cross-disciplinary field. Scientists from physics, chemistry, materials science and applied mechanics, all must participate in order to address issues related to mechanical properties, atomic structure, electronic bonding, and long term stability of interfaces at high temperature.

The objective of this workshop was to bring together people with different interests and expertise in an intensive, discussion oriented meeting so that fundamental issues for research in this important field could be identified.

Significant Findings

The workshop was held for two full days, on September 10 & 11, 1990, at the Aurora Inn, in Aurora NY, about twenty miles from Cornell's Ithaca campus. Thirty five scientists from outside Cornell and approximately ten scientists from Cornell attended the workshop. A mix of scientists from industry, national laboratories, and universities were represented. Two visitors from abroad, Dr. Harding from Harwell, England and Dr. Klomp from Eindhoven, the Netherlands came to the meeting. Altogether five sessions were held. Three on Monday (one after dinner in the evening) and two on Tuesday. A copy of the program and the attendance list (non-Cornell participants) are attached to this report.

The five sessions of the workshop were: (i) measurement of the local

shear and tensile properties of metal-ceramic interfaces, (ii) new metal-ceramic materials and ceramic fibers, (iii) constrained deformation in metal-ceramic composites, (iv) reactions at metal-ceramic interfaces and the effect of these reactions on mechanical properties, and (v) experimental and theoretical understanding of the atomic structure of metal-ceramic interfaces. About equal time was devoted to presentations and discussion. The lead talk at the meeting was given by Dr. Duhl from United Technologies who presented a historical perspective of how the application of superalloys evolved into single crystal technology. The main idea in that technology was to eliminate grain boundaries perpendicular to the tensile axis. In metal ceramic composites, strong and continuous ceramic fibers are expected to impart resistance to tensile failure; however, the fibrous microstructure introduces new issues which were clearly addressed at the workshop.

The workshop was forceful in identifying two broad concerns in the field: first, the engineering community is clearly in need of <u>scientific guidelines</u> for designing metal-matrix composites (for example putting the strongest ceramic fiber into the strongest metal matrix does not necessarily give the best composite), and second, much greater emphasis must be placed upon high temperature, strain rate sensitive, mechanical properties of metal-matrix composites.

The "physical metallurgy" of metal ceramic interfaces emerged as a critical area for future research. The topics here range from the understanding of the atomic structure of interfaces to the kinetics and thermodynamics of interfacial reactions that may produce new phases at interfaces. The influence of these phases on mechanical properties of interfaces must be studied. Since the reactions between ceramics and metals will depend on the activity of oxygen, the interfacial reactions

must be studied as a function of controlled oxygen partial pressure. For example, in one experiment the shear strength of an interface between nickel-oxide and platinum could be increased several fold by precipitating a 1 nm thick film of NiPt at the interface; the kinetics of the formation of this intermetallic layer was a strong function of the oxygen partial pressure.

The micromechanics of deformation and fracture at metal-ceramic interfaces was amply discussed at the workshop. While the recent advances in interface mechanics were recognized, a need was expressed for understanding the damage and deformation near interfaces on the scale of dislocation spacing. In-situ experiments were cited as one way of examining these local events. Further work is needed to relate interfacial fracture energy (the work of fracture) to interfacial bonding.

The theoretical and experimental understanding of the atomic and electronic structure of metal-ceramic interfaces appears to be an area that is ready for new breakthroughs. Desorption experiments using surface science techniques have the potential for direct measurement of the binding energy between metal atoms and ceramics. New concepts in the theoretical understanding of bonding is emerging that may well form the framework for future work in this area. These concepts revolve around electronic structure and the local dielectric properties of interfaces (it would appear that the hard sphere models that have been successful in explaining the structure of metals and other single phase materials cannot be directly applied to metal-ceramic interfaces). Here, the simple theoretical models of the Harwell group and the more detailed electron density calculations of the Anderson group at the Max Planck Institut in Stuttgart appear to provide the physical concepts as well as the tools for elucidating the fundmental physics of bonding at metal-ceramic interfaces.

Future Plans

A report based upon the discussions at the workshop will be prepared in January 1991 and circulated to all the attendees. After their comments are incorporated the manuscript will be submitted for publication in an international journal.

It is planned to hold a similar type of a workshop at the Aurora Inn in the fall of 1992.

Attachments

A copy of the program and the non-Cornell attendees is attached onthe following two pages.

AFOSR+ONR/CORNELL Workshop September 10-11, 1990
to be held at Cornell University, Ithaca, NY
Rosenstein/Fishman/Raj

TAILORED INTERFACES FOR HIGH TEMPERATURE METAL-CERAMIC COMPOSITES

**********DAY 1**********
Continuum Behavior

Overview and Purpose of the Meeting

A DEFORMATION CONSTRAINED BY METAL-CERAMIC INTERFACES

Discussion Leader: Ron Gibala

Single Crystal Superalloys-Design and Properties	Duhl
Interface Properties at Ambient Temperature	Gupta & Marshall
Interface Properties at Elevated Temperature	Jobin & Kennefick
Stress Relaxation in Metal Films Constrained by a Rigid Substrate	Li

B NEW METAL MATRIX COMPOSITE MATERAILS

Discussion Leader: Steve Fishman

Ceramic Fibers and Interfacial Compatability	Porter
Titanium Aluminide Composites	Bowden
Composites Made from Coated Fibers	Chyung
Alumina/Platinum Composites made by PVD	Lappalainen

C CONSTRAINED DEFORMATION IN METAL CERAMIC COMPOSITES — Evans

**********DAY 2**********
Atomistic Behavior

D REACTIONS AT METAL-CERAMIC INTERFACES

Discussion Leader: Neil E. Paton

Effect of Transition Metal Additives on Bonding	Klomp
Controlling Interface Strength by Intermetallic Layers	Sass
Oxidation Reactions	Rapp

E STRUCTURE OF METAL-CERAMIC INTERFACES

Discussion Leader: Jack M. Blakely

Dislocations Near Metal-Ceramic Interfaces	Ruhle(?Raj)
Electronic Structure	Lambrecht
Bonding of Metal Atoms to Ceramic Surfaces	Ohuchi
Space Charge Distribution Across Metal Ceramic Interfaces	Harding

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METAL-CERAMIC WORKSHOP ATTENDANCE LIST
Cornell/ONR/AFOSR
September 10-11, 1990
Aurora, NY